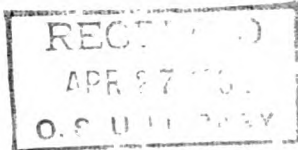


DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES

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METHOD AND COST OF QUARRYING, CRUSHING,
AND GRINDING LIMESTONE AT THE SECURITY QUARRY OF THE
NORTH AMERICAN CEMENT CORPORATION, SECURITY, MD.



BY

ALBERT W. COX

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METHOD AND COST OF QUARRYING, CRUSHING AND GRINDING LIMESTONE AT THE SECURITY QUARRY OF THE NORTH AMERICAN CEMENT CORPORATION, SECURITY, MD.¹

By Albert W. Cox²

INTRODUCTION

This paper, one of a series prepared for the United States Bureau of Mines discussing the methods used in mining, crushing, and grinding materials for cement manufacture, deals particularly with the methods used at the Security plant of the North American Cement Corporation.

These papers are designed to disseminate technical information regarding the methods used. The cost tabulations represent local operating expenditures only and not total production costs. It is recognized that publication of total production costs might in many instances cause embarrassment to individual producers as well as to the industry as a whole. On the other hand, operating costs are essential to the technical discussion and study of methods employed. The attention of the reader is specifically called to this differentiation in order that no misunderstanding of the scope of the cost tabulations shall ensue.

Quarrying operations at this plant are conducted primarily for the purpose of furnishing stone to the cement mill. The methods of quarrying, crushing, and grinding the raw materials are discussed in this paper, but later stages of the process of manufacturing cement are not included.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of the following persons in the collection of information: Charles Catlett, chemist and geologist, Staunton, Va.; J. J. Porter, vice president and general manager, North American Cement Corporation; E. S. Guth, district manager; P. A. Leichel, assistant superintendent; and C. E. Taylor, quarry foreman.

HISTORY AND GEOLOGY

The plant is located at Security, about 2 miles from Hagerstown, Md., on the Western Maryland Railway. It is served also by the Baltimore & Ohio Railroad and is within switching limits of the Pennsylvania and Norfolk & Western lines.

The original purchase of land was made after an investigation by Charles Catlett. The quantity of stone was estimated and determined entirely by a study of the geologic conditions and the natural exposure. The proximity to markets and the excellent railroad facilities were considered along with the suitability of the materials for cement manufacture. In 1906 cement was made in the laboratory of Booth, Garret & Blair of Philadelphia from large samples of materials taken from the property.

The quarry and cement plant were put into operation in the summer of 1908 under the name of Maryland Portland Cement Co. On November 1, 1909, the company combined with the Berkeley

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2 - One of the consulting engineers, U.S. Bureau of Mines, and experimental engineer, North American Cement Corporation

Limestone Co., with a lime plant at Martinsburg, W. Va., to form the Security Cement & Lime Co. On September 1, 1925, the company merged with the Helderberg Cement Co., with a cement plant at Howes Cave, N. Y., to form the North American Cement Corporation. On February 11, 1926, the Acme Cement Corporation, with a plant at Catskill, N. Y., joined the new corporation. The corporation now owns the three cement plants and the one lime plant.

In the early years of the Maryland Portland Cement Co. and its successor quarrying was done on a relatively small scale. Loading of stone was done by hand into small trucks, and quarry haulage was by mules over narrow-gage tracks. During the course of time, quarry operation was modernized by the use of steam shovels, larger cars, standard-gage tracks, and locomotive haulage.

The stone is of the Conococheague formation. It is uniformly low in magnesia, and the calcium carbonate content varies up to 90 per cent. The strike of the stone is about N. 15° E. The dip is nearly vertical, but its direction changes rather markedly at an overthrust near the west end of the present quarry working face (see fig. 1).

The overburden varies from nothing to 15 feet, with an average depth of about 2 feet. It consists largely of smooth clay.

PROSPECTING AND SAMFLING

The property was originally prospected about 1906. No deep drilling was done during the first or later stages of the prospecting. All samples taken were from the surface, but an effort was made to get unweathered rock, and allowances were made for changes which might reasonably be due to proximity to the surface. An area of about 100 acres was sampled in this way, the spacing of sampling points depending to some extent on the location of the outcrops. Samples were analyzed for lime, silica, iron, alumina, and magnesia.

The nearly vertical dip of the rock causes surface exposure of the strata, so that outcrops are numerous and representative. Drilling was not considered necessary or desirable, for drill samples might have been misleading due to their including only small sections of the strata. The sampling of surface-exposed rock was simpler and cheaper, and the results of such sampling when considered together with the geology of the district were entirely satisfactory. The cost of all the prospecting done previous to the purchase of the property was about \$500. Additional investigations and surveys were made after the purchase of the property, but these merely served to confirm the results of the original examinations.

About three years ago prospecting of the land east of the present quarry was done by drilling the numerous outcrops with hand drills, and exploding small charges of dynamite to expose fresh stone. Nineteen points spaced pretty well over the 20 acres were thus sampled, the samples were analyzed in the plant laboratory and the results plotted on a map of the property. No deep drilling was done during this prospecting work.

The chemical make-up of the stone is important, and the drill muds from the blast holes are sampled and analyzed regularly. Samples are taken at 5-foot intervals during the drilling of the holes, and the separate samples are analyzed for calcium carbonate, with occasional complete analyses of composite samples representing several holes.

QUARRYING METHODS

The quarry as now worked consists of two levels. The upper level is a natural quarry formed by Antietam Creek cutting into the flank of the limestone formation. The recently-opened lower level is an open pit started in the floor of the upper level and as yet is not sufficiently developed to furnish a large part of the total production.

Figure 2 shows a plan of the upper and lower levels of the quarry, tracks, crushing and storage plant, etc. Figure 1 shows an elevation of the present working face, indicating the

Conococheague limestone

KEY

	80 per cent calcium carbonate
	85 do.
	90 do.

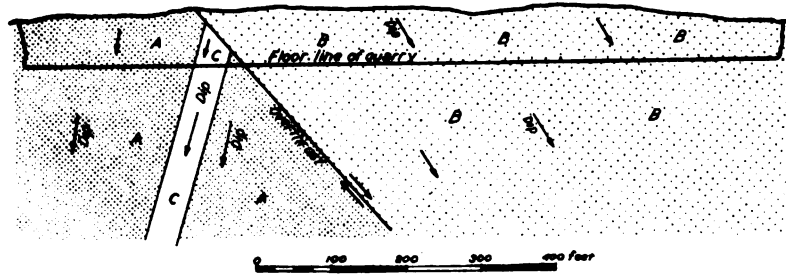


Figure 1.—Elevation of upper level quarry working face, looking N.N.E. showing the part of face running N.N.W. and E.S.E. (about at right angles to strike of the strata). Face at eastern end of quarry, running nearly N and S, is not shown.

KEY

1. Quarry, upper level
2. Quarry, lower level
3. Loop track, standard gage
4. Clay track
5. Clay storage
6. Loaded-car track
7. Empty-car track
8. Spring switch
9. Hoist, lower level
10. Hoist, serving crusher
11. Track and trestle
12. Primary crusher
13. Inclined belt conveyor
14. Hammer mill
15. Stone storage
16. Gyratory crusher
17. Screen and bins
18. Track
19. Shop and air compressor
20. Auxiliary clay storage

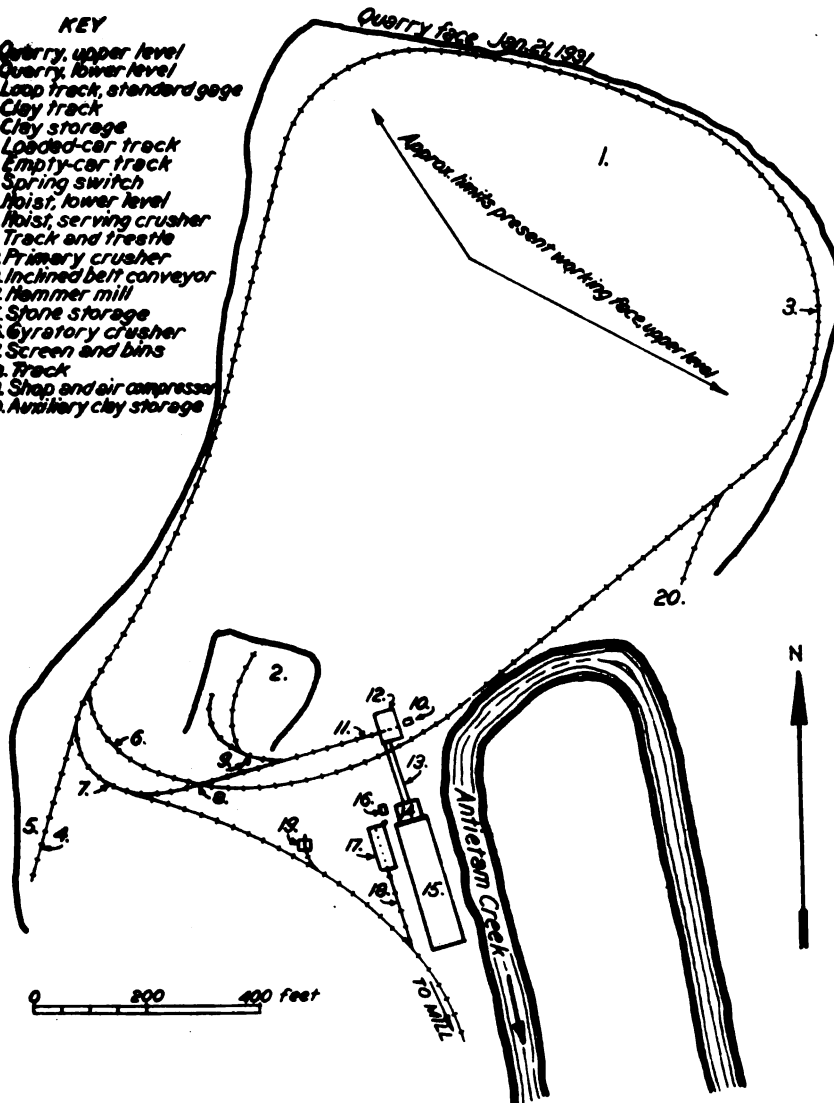


Figure 2.—Plan of quarry and crushing plant

change in the dip of the rock at the overthrust, etc. It does not show the east end of the quarry, where the working face swings around to a nearly north and south direction. The face here advances into the dip of the rock and runs parallel to the strike. The larger portion of the working face, running nearly east and west, is at right angles to the strike of rock.

The overburden is highly siliceous; a representative analysis of it is as follows: SiO_2 , 64.0 per cent; Al_2O_3 , 19.4 per cent; Fe_2O_3 , 3.2 per cent; CaO , 1.7 per cent; MgO , 1.7 per cent; ignition loss and undetermined, 10.0 per cent. Silica, iron, and alumina are necessary components of the cement raw mix, so that a certain amount of this overburden is used. But the distribution of overburden is not uniform, and as its quantity exceeds that needed some stripping is done.

Stripping is done at intervals of several months by a contractor who is paid on the basis of the number of trucks of material hauled. A gasoline-powered Keystone grader with $\frac{1}{2}$ -yard scoop loads the overburden onto auto trucks which transport it about $\frac{1}{4}$ mile to the clay storage, where it is dumped over the edge of the old quarry onto the quarry floor. The location of the clay storage on the floor of the upper-level quarry is shown by points 4 and 5 in Figure 2. The clay is taken from storage as needed and put through the crushing and grinding system with the limestone.

Approximately 4,700 tons of overburden was removed in 1930. The contractor was paid \$2.50 per truck load or approximately 50 cents a ton. The total overburden removed by stripping amounted to about $1\frac{1}{4}$ per cent of the total quarry output (stone plus used clay) for the year. All this stripping was done in the spring of the year.

Although most of the stone and clay quarried is used in the cement raw mix, a small percentage of clay-free stone is sent to a separate secondary crusher and screening plant to be sold as commercial stone. Of the total quarry output of 327,100 tons stone (including and used-clay) in 1930, 17,000 tons of clay-free stone was sold in assorted sizes ranging from $2\frac{1}{2}$ -inch down to screenings. This tonnage represented between 5 and 6 per cent of the total quarry output. The crushing and screening plant for handling commercial crushed stone operates intermittently as needed.

There is no waste from the quarry, except that in some of the previous major stripping jobs the clay (overburden) was wasted. In more recent stripping (that of last year), the clay was stored for future use. With the exception of the crushed stone sold for commercial uses, all the material passes through the several stages of reduction until it is of the high degree of fineness necessary for the cement raw mix.

The quarry has two levels as previously described. The face of the upper level varies in height from 50 to 80 feet, and the present working face is about 1,600 feet long, running nearly east and west but swinging around at the creek end until it runs nearly north and south (See fig. 2).

The face of the lower level is about 40 feet high now, but this height will be increased to 50 feet as the quarry is developed. The floor of this level is about 30 feet below the surface of Antietam Creek, so that it is necessary to pump drainage water from a sump back to the creek. This is done by a centrifugal pump driven by a 10-hp. electric motor. There is natural drainage from the upper-level quarry.

The output of stone plus clay from the quarry (both levels) varies from about 1,600 tons per day for full plant operation to about 1,000 tons per day for restricted plant operation, with the tonnage somewhat higher when the commercial stone plant is operating. The quarry operates in daylight only, nine hours a day, about 280 days a year. It does not operate on Sundays and there is a shutdown of some weeks during the winter.

Drilling

Three drills are used for primary drilling of blast holes. One Loomis "clipper" drill is powered by a 15-hp. electric motor, using 440-volt alternating current; two Keystone drills are powered by steam. They are belt-driven and are of the traction type. The electric drill is liked best, for its ease of starting and for the convenience of power supply. Comparative operating costs for the different drills are not available, nor are figures for the total feet drilled by the individual machines. However, the following average figures for the year 1930 are indicative of the drilling experience here:

Total feet drilled, 1930 (primary blasting only).....	9,300
Total quarry output, 1930 (tons stone plus clay).....	327,100
Total feet drilled per 1,000 tons quarry output.....	28.4
Total tons per foot of hole drilled.....	3.52

These figures relate to drilling for primary blasting only and do not include that done for secondary blasting (by a different type of drill). The drilling speed of the blast-hole drills is about 3 feet per hour of total time per machine: it is somewhat higher per hour of drilling time.

The bits used by the blast-hole drills are of steel, and are 6 inches in diameter by 4 feet long. They are sharpened in the quarry shop by a Gill compressed-air bit sharpener after drilling 40 or 50 feet.

During the primary drilling, pieces of iron pipe 7 inches in diameter by 4 to 6 feet long are used to case through the overburden. The pipe is left in the hole until the hole is loaded when it is pulled out and saved for future use.

The holes are placed 25 feet back from the quarry face and are spaced 15 feet apart; they extend to a point about 5 feet below the quarry floor and are from 55 to 85 feet deep. This spacing was found to give the best results after experimenting during the course of two or three years. The holes are 6 inches in diameter. The hole locations (previous to drilling) are laid off by measurement and are indicated by stakes.

Drilling operations are made difficult by the number of mud seams encountered, these seams being numerous near the east end of the quarry face. Clay pockets have at times been so troublesome that concrete was poured into the hole to prevent the sides from falling in. Caves are rare, but one large one was encountered near the middle of the working face of the upper level; it was necessary to bridge over this cave with wooden beams when moving the shovel over it. The stone toward the west end of the quarry is lower in calcium carbonate (see fig. 1) and thus somewhat harder, which slows up drilling to some extent. On the whole, however, the most trouble is encountered with the mud seams near the east end of the quarry. The percentage of holes lost is low, probably not over 1 or 2 per cent.

Secondary drilling is done by one tripod drill and five jackhammer drills, using compressed air at a pressure of 100 pounds per square inch. Air is supplied by a Worthington 13 by 14 inch air compressor driven by a 100-hp. electric motor and located in the quarry shop. The 3-inch pipe line near the compressor is buried, but the 1-inch pipe lines distributing air to drills are laid on the ground. The tripod drill uses steel $1\frac{1}{2}$ inches in diameter by 7 to 20 feet long, and the jackhammers use steel $\frac{1}{2}$ inches in diameter by 2 to 20 feet long.

Blasting

The arrangement of dynamite in the holes is as follows: 50 to 150 pounds of 75 per cent quarry gelatin at the bottom of each hole; 200 to 250 pounds of 60 per cent quarry gelatin

next; 100 to 200 pounds of 40 per cent Red Cross ammonia dynamite next; and 20 to 25 feet of stone screenings on top. The dynamite is stopped 20 to 25 feet from the top of all holes. Most holes are loaded solidly with dynamite up to the stone screenings, but in some holes where the stone is expected to break easily the dynamite charges are alternated with 5 to 12 feet of stone screenings.

Covered cordeau is used in the holes and for the header; no plain cordeau is used. The cordeau is fastened to the first stick of quarry gelatin put in the hole. A No. 6 detonator is used at one end of the header to detonate the cordeau. The 2 feet of fuse attached to the detonator is lighted with a match. No battery is used for blasting.

A powder crew of 6 men loads the holes at the rate of about 20 minutes per hole. The crew divides the work as follows: 2 men haul dynamite, 1 opens boxes, 2 load dynamite into holes, and 1 pours stone screenings into holes. No primers are used and no springing of holes is done. The stone screenings used in the holes are not tamped down. Twenty holes are blasted at one time, and the stone obtained is sufficient to last from 60 to 90 days. The normal fragmentation obtained results in stones of 2 to 3 tons and smaller, but an occasional stone of 20 tons or more is obtained.

The track along the quarry face and for a safe distance back along the loop is removed before primary blasts are set off. The track is removed by hand labor, the rails and ties being piled on a small flat car which is moved by hand from the danger zone. After the blast and some preliminary cleaning up, the track is replaced.

In secondary blasting, the larger blocks of stone are drilled but the smaller pieces are mud-capped. The secondary blasting is probably about equally divided between these two types of shots. Ammonia dynamite of 40 per cent strength in $1\frac{1}{4}$ by 8 inch sticks is used. Clover-brand fuse and No. 6 detonators are used, the length of the fuse being 2 feet and its burning time 1 minute and 40 seconds, a rate of 50 seconds per foot.

Two men work full time on primary drilling, and three to four men (the blaster part time) on secondary drilling. The men on primary drilling are paid by the foot drilled and those on secondary drilling by the hour.

The following figures for 1930 show the grades and quantities of dynamite used:

Total tons of stone quarried (including 1 to 2 per cent of overburden).....	327,100
Pounds of dynamite used for primary blasting (sticks 4 and $4\frac{1}{2}$ in. diam. x 16 in. long):	
75 per cent quarry gelatin.....	6,600
60 per cent quarry gelatin.....	24,500
40 per cent Red Cross extra.....	<u>22,200</u>
Total.....	53,300
Pounds of dynamite used for secondary blasting (sticks $1\frac{1}{4}$ in. diam. x 8 in. long):	
40 per cent Red Cross extra.....	49,800
40 per cent straight.....	22,700
Extra D.....	<u>1,900</u>
Total.....	74,400
Pounds of dynamite used, all blasting.....	127,700
Tons of stone per pound of dynamite:	
Primary blasting.....	6.14
Secondary blasting.....	4.40
All blasting.....	2.56

Loading

All stone and clay (from storage) is loaded by shovels, the shovel equipment being as follows:

- 1 Marion "75" steam shovel, 100-ton, railroad-type, half-revolving, $3\frac{1}{4}$ -yard dipper.
- 1 Marion "60" steam shovel, 80-ton, railroad-type, half-revolving, $2\frac{1}{4}$ -yard dipper.
- 1 Marion "70-E" electric shovel, 110-ton, caterpillar-type, half-revolving, $3\frac{1}{4}$ -yard dipper.
- 1 Thew "A-1" steam shovel, 22-ton, traction-type, full-revolving, $\frac{1}{2}$ -yard dipper.

The two Marion steam shovels are now serving the upper quarry level. The electric shovel is on the lower level. The Thew steam shovel handles clay from the clay storage.

The electric shovel is liked best because of performance, convenience of power supply, and ease of movement with its caterpillar treads. Electric current is brought to it by a 4-conductor rubber-covered cable 500 feet long, which is laid along the ground and covered with pieces of old conveyor belt. The shovel operates on 2,300-volt alternating current. The two Marion steam shovels each require a fireman, an engineer, and a craneman, whereas the electric shovel requires only an engineer and a craneman. The Thew steam shovel, because of the intermittent character of its work at the clay storage, uses only one man.

It is difficult to compare the loading speeds of the shovels, for they are at times handicapped by the necessity for blending the stone. In order to obtain thorough blending of stone of different chemical characteristics, the relative number of cars loaded by the different shovels is varied. Thus, the schedule of loading at a certain time may be four cars from one shovel, to one car from another, to three cars from the third. At the same time the shovel serving the clay storage pile might be loading clay for storage in cars until used. This schedule would be maintained until the blending requirements dictated another schedule.

Haulage

All tracks in the quarry and throughout the cement plant are standard gage. Sixty-pound rails are used in the quarry and eighty-five-pound rails in the track between the quarry stone storage and the cement mill. The track along the quarry face is not ballasted, but the permanent loop of the track is ballasted. The arrangement of the loop track in the quarry is shown in Figure 2. The quarry track is for the most part about level, with an occasional slight grade. But there is a sharp incline, of about 23 per cent grade, from the lower level to the upper level; and a second one, of about 13 per cent grade, from the upper level to the dumping platform at the primary crusher. A single-drum hoist served by an 82-hp. electric motor pulls one car at a time from the lower level; and a Flory hoist served by a 125-hp. electric motor pulls one car at a time to the crusher for dumping. The maximum grade of the track between the quarry stone storage and the cement mill is about 5 per cent, with an average of about 2 per cent.

One Vulcan saddle-tank steam locomotive of 26 tons serves the quarry, and a second identical locomotive transfers stone from the quarry stone storage to the cement mill.

In picking up loads and placing empty cars on the upper quarry level, the locomotive reverses its direction of travel on alternate trips. Each time it pulls the empties and

pushes the loads. The tracks are equipped with spring switches, so that the switching is done automatically. There is no time lost in waiting for empty cars at the shovels (other than that due to the schedule of loading).

The quarry-car equipment consists of 22 special Earnshaw-type, 7-yard, 10-ton, side-dump cars. With the loop arrangement of the track, the dumping side of the cars is always on the proper side when the cars are placed at the crusher. Because the number of cars loaded by the different shovels varies due to the loading schedule, the number of cars per train varies from 5 to 8. These trains are delivered at the foot of the short incline leading up to the crusher, and the cars are placed singly for dumping by means of the electric hoist. The length of haul from the most distant point of the working face on the upper level to the primary crusher is about $\frac{1}{4}$ mile, with an average haul of 2,000 feet.

CRUSHING, DRYING, GRINDING METHODS

With the exception of the crushed stone sold for commercial uses, the crushing, drying, and grinding of the stone (plus clay) is done to reduce it to the high degree of fineness required for the cement raw mix. The stone (plus clay) passes successively through a jaw crusher, a hammer mill, rotary dryers, a second hammer mill, and finally through a Hardinge air-swept mill and Fuller mills. The jaw crusher, the first hammer mill, and the rotary dryers handle, in turn, the full tonnage of material; the second hammer mill is served by a Hummer screen which by-passes about one-fourth of the total tonnage, sending three-fourths of it to the hammer mill; the material then goes to the Hardinge mill and 14 Fuller mills, each mill receiving a portion of the total tonnage, and delivering material of the required fineness.

Before the material reaches the grinding mills, a final correction of chemical composition is made by adding cinders. The cinders are rich in silica, iron, and alumina and are used to increase these constituents of the cement raw mix. They are purchased from the railroad companies, are crushed in a small hammer mill, dried in a rotary dryer, and meet the stone (plus clay) at the proportioning scales ahead of the grinding mills. The percentage of cinders averages about 6, so that the total tonnage handled by the grinding mills is about 6 per cent greater than that handled by the crusher and hammer mills.

A flow sheet of the crusher, hammer mills, etc., is shown in Figure 3. The jaw-crusher and hammer-mill output averages 135 tons an hour including time running empty; their capacity output is 200 tons an hour. The Fuller-Lehigh mill has an output of 3.4 tons per mill-hour when receiving minus $\frac{1}{2}$ -inch feed; with present practice the feed is minus $\frac{1}{4}$ -inch. The Hardinge mill output is not shown. A detailed description of the flow sheet follows:

The primary crusher is located in the quarry, the pit beneath it extending several feet below the floor of the upper-level quarry, but the dumping platform at the crusher is about 12 feet above the level of the quarry floor. The crusher is an Allis-Chalmers Blake-type, with a 48 by 60 inch opening, a fly-wheel 21 inches wide by 10 feet in diameter, and is driven at 156 r.p.m. through a 20-inch belt by a 200-hp., 440-volt, induction motor. Quarry cars are placed for dumping, one at a time, by an electric hoist, and a second single-drum hoist driven from the crusher motor is used to dump the load from the side-dump car into the crusher.

The crusher receives stone in sizes ranging from 4-foot down, and through its 9-inch opening discharges stone ranging from 9-inch down. One crusher attendant places the cars for dumping, dumps them, aids in releasing large stones stuck in the crusher, etc. In dumping cars he tilts the car gradually, allowing the stone to feed into the crusher at the proper rate. A second attendant feeds the crusher (loosening large stones), oils, cleans up, etc.

The stone discharges from the jaw crusher onto a belt conveyor, on which it is carried to a gyratory crusher (for commercial crushed stone only) or to a hammer mill (for the cement

raw mix). The belt is rubber-covered, 48 inches wide, 120 feet between centers, inclined 17°, and travels at the rate of 230 feet per minute.

The gyratory crusher is a No. 7½ Austin, driven by a 75-hp. electric motor, and it receives stone in sizes from 9-inch down and discharges stone in sizes from 2½-inch down. It delivers to a bucket elevator made of 26-inch belt and 24-inch buckets, inclined 64°, and 50 feet high, which in turn delivers to a revolving screen. The elevator and screen are driven by a 60-hp. induction motor. The screen which is over the stone bins is 5 feet in diameter by 57 feet long, and is made up of sections with punched holes of ¼, 1, 2, and 3-inch diameter. The stone sorted by this screen falls into five rectangular steel bins of about 100 tons capacity each, whence it is drawn into automobile trucks or railroad cars for shipment. Clay-free stone only is put through this part of the crushing system and all the material handled here is sold for commercial use, none of it going to the cement raw mix. The tonnage so disposed of represents about 6 per cent of the total quarry output.

The hammer mill used for secondary crushing in the cement manufacturing system is a Pennsylvanis, size SXT-14, equipped with a Pennsylvania size-50 apron feeder, and driven direct by a 720 r.p.m. by a 400-hp. induction motor. The mill receives stone in sizes ranging from 9-inch down and discharges it in sizes from 1-inch down. During wet weather care must be exercised to see that clay does not reach the hammer mill in large lots, else the mill becomes choked. But by distributing the clay through the total tonnage handled, the normal amount of clay can be handled by the hammer mill even in the worst weather. One man tends the hammer mill, the stone storage, the belt conveyor, does oiling, etc. This hammer mill and the primary jaw crusher operate about 10 hours a day.

The stone from the hammer mill discharges into a bucket elevator, with 30-inch belt, 51 feet between centers, inclined 65°, lift 46 feet, speed 235 f.p.m., which carries it to the belt conveyor distributing to the stone storage. This horizontal belt conveyor runs the full length of the enclosed stone storage; and is of 6-ply rubber-covered belt, 36 inches wide by 228 feet between centers, travelling at 220 f.p.m., and driven by a 40-hp. induction motor. The stone is discharged from the belt at any desired point, or along the full length of the storage, by a Robins No. 3 high tripper with No. 2 type chute. This tripper may be fixed in one position or may be set to move slowly back and forth over the full length of the storage, distributing the stone as it moves.

The stone storage is a roofed concrete building, without bins, 230 feet long, 50 feet wide and 12 feet high at side walls, with a 45° roof of 24-gage corrugated iron on a steel frame. The capacity is 11,000 tons of stone. Two parallel tunnels run the length of the building beneath the floor, each tunnel containing a belt conveyor 24 inches wide by 226 feet between centers. Each tunnel has 23 cast-iron reciprocating cradle feeders to deliver stone from storage to the belt conveyor. Any number of feeders from 1 to 46 can be run at one time in delivering stone and this makes it possible to blend the stone thoroughly. The plant chemist informs the storage attendant what feeders he is to operate. In this storage and all through the crushing and grinding system (except at the gyratory crusher for commercial crushed stone), the stone contains 1 or 2 per cent of clay.

One tunnel belt conveyor delivers onto a cross belt conveyor which discharges into an elevator at the south end of the storage building; the second tunnel belt delivers directly into the elevator. The cross belt conveyor at the recovery end of the tunnel is 24 inches wide by 25 feet between centers, and it delivers into a bucket elevator with 32-inch belt, 30 by 12 by 15 inch buckets, inclined 65°, with a lift of 44 feet, which in turn discharges into a steel loading bin of 60-ton capacity. The tunnel belts, reciprocating feeders, elevator, etc., are driven by a 75-hp. induction motor.

Stone is drawn from the steel loading bin into 50-ton steel railroad-type hopper cars placed beneath it, which are hauled singly to the reinforced concrete hopper beneath the

track at the cement mill, a distance of $\frac{1}{4}$ mile. This transferring of stone from storage to mill is usually done at night only, because there is less interference with quarry operation and so the locomotive is available for emergency day use.

Stone is fed from this concrete hopper by a cast-iron reciprocating cradle feeder, 18 inches wide, which delivers it into a bucket elevator, with 36-inch 10-ply belt, inclined 64° , with a lift of 77 feet, and speed of 255 f.p.m. This elevator delivers into a concrete stone bin, 17 feet wide by 49 feet long by 30 feet high, with a capacity of 1,200 tons. The five 12-inch cast-iron reciprocating cradle feeders beneath this bin discharge the stone onto a belt conveyor, 22 inches wide by 66 feet between centers, over the discharge end of which is suspended a magnet for removing tramp iron. This belt delivers into a chain-and-bucket elevator, 32 feet high, with a 7 by 12 inch bucket at every second link, which in turn delivers through chutes (without intervening feed bin) to the two stone dryers.

Drying

The two Vulcan rotary dryers used for drying stone are of 5-foot 6-inch diameter, 50 feet long, and driven at 3 r.p.m. by a 40-hp. electric motor. They are fired by Fuller-Kinyon pulverized-coal burners, each served by a Buffalo fan with a 2-hp. electric motor; each burner screw is driven by a 1-hp. electric motor. The gases of combustion and the stone pass through the dryers in opposite directions and are in direct contact. The moisture in the material entering the dryers varies from 2 to 4 per cent with weather conditions; that in the dried material is about one-seventh of 1 per cent. The dryers are run intermittently through 24 hours a day, for although all the stone must be dried it is not necessary to operate full time to do the work.

Cinders, purchased from the railroad companies and crushed in a Jeffrey type-B hammer mill, 24 by 36 inches in size driven directly by a 50-hp. electric motor, are dried in an similar dryer housed in the same building, the three dryers lying parallel to each other. The cinders pass to a storage tank, whence they are drawn out and delivered by an elevator to the proportioning scales which are described later.

Vibrator Screen

The chain-and-bucket elevator, with concrete casing and 62 feet between centers, that receives the stone from the rotary dryers delivers it to a Hum-mer electric vibrating screen, type 60, size 4 by 7 feet, with $\frac{1}{4}$ -inch screen openings. This screen passes directly about one-fourth of the total tonnage handled, and sends three-fourths to the hammer mill, whence it passes to the same elevator and screen.

Secondary Crushing

The hammer mill is a Pennsylvania SXP-8, with 42-inch hammer circle, and is driven directly at 900 r.p.m. by a 200-hp. electric motor. It is located on the floor level of the dryer building, between the two stone dryers. It receives stone in sizes from 1-inch down, and reduces it to minus $\frac{1}{2}$ -inch (grate-bar opening is $\frac{1}{2}$ -inch). It runs intermittently.

The stone passing the Hum-mer screen falls into the chain drag below; this is a Link-Belt No. H480 chain, 16 inches wide and 66 feet between centers, with head shaft driven at 8.8 r.p.m. through a No. 8HD James speed reducer by a 20-hp. electric motor. This chain distributes the stone to the group of 8 concrete bins below it, with a total storage capacity of 1,400 tons.

Below the bins the stone is drawn out through short chutes equipped with slides for regulating the rate of flow, onto two belt conveyors 18 inches wide by 57 feet between centers, which discharge into a 12-inch by 15-foot screw conveyor. The chain-and-bucket elevator receiving from the screw is about 46 feet high, with 7 by 12 inch buckets, driven by a 25-hp. electric motor (which also drives the cinders elevator); it delivers to a small feed bin serving the proportioning scales.

Blending

The stone and cinders are proportioned at the Schaffer scales, the stone side using a 36-inch belt conveyor and the cinders side a 14-inch belt. The proportioning for the cement raw mix is obtained by moving the weights on the two lever arms, which in turn control the opening of the gates over the belts and thus control the quantity of material delivered by the scales. The stone and cinders meet at the point of discharge of these two belts, whence they pass to an inclined belt conveyor, 22 inches wide by 51 feet between centers, which delivers into the 12-inch by 62-foot screw conveyor that distributes the material to the concrete feed bin over the Fuller mills.

A temporary elevator takes material for the Hardinge mill from the automatic scales at the point of discharge (but before the inclined belt conveyor) and delivers it to the steel feed bin at the Hardinge mill. This elevator will be replaced later by a permanent arrangement.

Dust from the cement kiln gases is settled by means of a Cottrell electrical precipitator, and is returned to the system, meeting the stone on the belt below the concrete stone bins and just ahead of the automatic scales. But the dust collection and transportation system will not be described here, for it has just been placed in operation and does not have an important bearing on grinding practice.

Grinding

Up until the past winter the grinding of stone (plus clay and cinders) was all done in eighteen 42-inch Fuller-Lehigh pulverizer mills, with fan discharges. But during the winter a Hardinge air-swept mill was installed, four Fuller mills being removed to make room for it, and it is expected that the 14 Fuller mills still in use will be removed and replaced with two additional Hardinge air-swept mills. The experience with the Hardinge mill is as yet somewhat limited, but it is expected to effect savings in power and labor and a substantial saving in repairs and operating supplies.

The present grinding equipment consists, then, of the following machines:

One Harding steel-plate ball mill of 10-foot diameter and 66 inches long, with Hardinge 2-D constant weight feeder; 6-foot 6-inch rotary classifier; stationary classifier; Clarage fan, size 110, type 1; and collector. The mill is driven at 17.7 r.p.m. by a direct-connected 400-hp. supersynchronous motor, 2,300 volts; the fan is driven at 875 r.p.m. by a 150-hp. induction motor, 2,200 volts.

Fourteen Fuller-Lehigh pulverizer mills, 42-inch, fan discharge, all belt-driven at 160 r.p.m., 6 individually by 75-hp., 440-volt, vertical electric motors, 2 by one 150-hp., 440-volt motor, 6 by two 300-hp., 2,300-volt motors.

In the air-swept Hardinge mill the air current carries material from the mill to the classifiers and collectors, thus relieving the mill of the work of grinding material that is already sufficiently fine.

All the mills receive material $\frac{1}{4}$ -inch and less in size; the Hardinge mill delivers a product with 91 per cent passing a 200-mesh sieve, and the Fuller mills (with their present 40-mesh screens) a product with 84 per cent passing 200 mesh.

An accurate indication of power consumption in the Hardinge mill has not yet been obtained. The department power consumption for 1930, when all grinding was done by the Fuller mills, and when feed was $\frac{1}{4}$ -inch and smaller, and including power for the dryers, cinders mill, hammer mill at dryers, etc., averaged 21.6 kilowatt hours per ton ground. Unless otherwise stated in the text, all motors are driven by 440-volt current.

Fineness of the ground product is checked hourly 24 hours a day by the laboratory staff. Fineness of the product from the Hardinge mill is governed by various settings in the air-classification system; fineness of the product from the Fuller mills is governed by the rate of feed of material to the mills and by the mesh of the screens used in the mills.

The rates of output of the crusher, hammer mills, etc., are shown by the following table the figures represent the average rate of output in 1930 and not necessarily the capacity of the machines.

Rate of output of machines

Machine	Tons output per machine hour
Allis-Chalmers jaw crusher (48 x 60 in.)	¹ 135
Pennsylvania hammer mill (SXT-14)	¹ 128
Pennsylvania hammer mill (SXP-8)	75
Fuller-Lehigh pulverizer mills (42 in.)	² 3.4

- 1 - Average rate of output, including time running idle; capacity is about 200 tons an hour.
- 2 - When receiving minus $\frac{1}{4}$ -inch stone; present practice is minus $\frac{1}{4}$ -inch stone.

Note.- The Hardinge mill has not yet been in operation long enough to obtain an accurate measure of output. It is guaranteed to grind 22 tons per mill hour.

In 1930 the Pennsylvania SXT-14 hammer mill at the quarry used two sets of manganese-steel hammers (45 to the set); the Pennsylvania SXR-8 hammer mill at the stone dryers used five sets of manganese steel hammers (36 to the set).

The following figures for 1930 will indicate the consumption of the principal replacement parts in the eighteen 42-inch Fuller-Lehigh mills:

Material ground, 328,700 tons (stone plus clay plus cinders).

Machine parts	Total used	No. used per 10,000 tons ground
Balls (12 $\frac{1}{4}$ in. diam.)	96	2.92
Pushers	76	2.31
Perforated protecting screens	40	1.21

The personnel of the handling, drying, and grinding department at the mill is as follows (supervision is by the cement-mill general foreman):

Number of men	Job	Hours per shift	Number of shifts per 24 hours	Man-hours per 24 hours
1	Unloading cinders cars, running cinders hammer mill, etc.	8	1	8
2	Operate transfer elevator (at point of dumping cars) 3 dryers, 1 hammer mill, clean up, etc.	8	3	48
1	Repairing at dryers, etc.	8	1	8
1	Storage-bin attendant, proportioning scales, Hardinge and Fuller mills feed bins, etc.	8	3	24
1	Operates 1 Hardinge mill and 14 Fuller mills	8	3	24
2	Repairing grinding mills, etc.	8	1	16
1	Sweeping in grinding department.	8	1	8
Total	-	-	-	136

The ground material leaving the Hardinge mill and Fuller-Lehigh mills is cement raw mix, and after further blending in storage silos it is burned in the rotary kilns.

SAFETY AND FIRST-AID WORK

The plant personnel has been active in safety work and the efforts of last year were rewarded by passing through the full calendar year without a single lost-time accident. The record of the quarry has been more outstanding than that of the cement plant; at the time of writing this it has been 600 days since the last lost-time accident in the plant, but 960 days since the last one in the quarry.

The plant safety committee is made up of foremen and department heads, with the assistant superintendent acting as chairman. Meetings are held once a month, on Friday afternoons. Mass meetings of all the men of the plant are held occasionally and at such times outside speakers are obtained to talk to the men.

In addition to the plant safety committee, there is a group known as the Distinguished Service Club. This club is composed of workers of all ranks who have shown unusual interest in safety, who have clean accident records, or who have otherwise distinguished themselves in the safety cause. Any member of the plant safety committee may nominate a worker for membership in the club, and the committee votes on the nomination. One member is elected each month and the oldest member is dropped, this being done to maintain the active membership at 12 men. The member elected each month is given a button to wear, which he retains permanently.

Bulletin boards are maintained in each plant department and the safety bulletins are changed frequently. A housekeeping inspection of the whole plant is made monthly by two workmen appointed anew for each inspection and the departmental ratings are posted on bulletin boards.

Mechanical safeguards are used throughout the plant, but care on the part of the workman is absolutely essential to the prevention of accidents, and the past success of the quarry and plant has been due to enlisting the interest of the workmen in the safety movement.

First-aid training, using the Bureau of Mines methods, is conducted in the plant, having been carried on at intervals since 1924. Most of the quarry and plant men have had first-aid training, and one team is kept in active training.

QUARRY ORGANIZATION AND SCALE OF WAGES

The character of the quarry organization is indicated by the following table of workmen employed:

1 quarry foreman
2 well drillers
3 tripod and jackhammer drillers
2 blasters (1 acts as quarry subforeman)
3 shovel engineers
3 shovel cranemen
2 shovel firemen
2 locomotive engineers (1 in quarry; 1 transfer storage to mill)
1 track-maintenance man
1 coalman (hauls coal from mill to quarry and distributes to shovels, etc.)
1 night watchman
1 head repairman (in shop at quarry)
1 blacksmith
1 blacksmith helper
1 cable hooker (at foot of jaw-crusher incline)
1 hoistman
1 crusher feeder
2 crusher attendants
1 storage man

The total quarry force, including crushing department, but not including cinders department, drying, final hammer mill (after dryers) and grinding, is 30 men. The quarry foreman is paid a monthly salary; the well drillers are paid a rate varying from 30 cents per foot on the top level to 27 cents per foot on the lower level for the steam drills, and from 28 cents per foot on the top level to 25 cents per foot on the lower level for the electric drill; the other workmen are paid by the hour, their rates varying from a high of 68 cents to a low of 37 cents, with an average of 51 cents per hour.

QUARRYING, CRUSHING, AND GRINDING COSTS

Costs of quarrying and crushing stone (plus 1 to 2 per cent clay), and grinding stone (plus 1 to 2 per cent clay, plus 6 per cent cinders) are given in the following tables. All the figures shown are based on operation for the full year 1930. Quarry costs per ton of dry stone quarried (including 1 to 2 per cent clay overburden) for 1930 when 327,100 tons was produced are as follows:

	<u>Per ton</u>
All labor	\$0.1348
Supplies other than power, fuel, explosives	.0302
Electric power	.0014
Coal (shovels and loco- motives	.0137
Explosives	.0550
Stripping	<u>.0072</u>
Total cost	0.2423

The cost of crushing 327,100 tons of dry stone (including 1 to 2 per cent clay overburden) in a jaw crusher and one hammer mill, reducing stone from shovel size to 1 inch and less in 1930 was as follows:

	<u>Per ton</u>
All labor	\$0.0303
Supplies other than power and fuel	.0120
Electric power	.0020
Coal for locomotive (haul- ing stone from storage to mill)	<u>.0029</u>
Total cost	0.0472

The following table shows the cost of drying stone (including 1 to 2 per cent clay overburden), of crushing it in the final hammer mill, of drying cinders, and of grinding the stone plus clay plus cinders in eighteen 42-inch Fuller-Lehigh pulverizer mills; and reducing the material from minus 1-inch to 84 per cent minus 200-mesh (1930; tons stone plus clay, 309,800 tons cinders, 18,900; tons mixture, 328,700).

	<u>Per ton</u>
All labor	\$0.0733
Supplies other than power and fuel	.0690
Electric power	.0225
Coal to dryers	<u>.0412</u>
Total cost	0.2060

The cost of handling and delivering purchased cinders to dryer is not included in the table. The plant makes its own electric power; waste-heat boilers utilize the heat of the exhaust kiln gases.

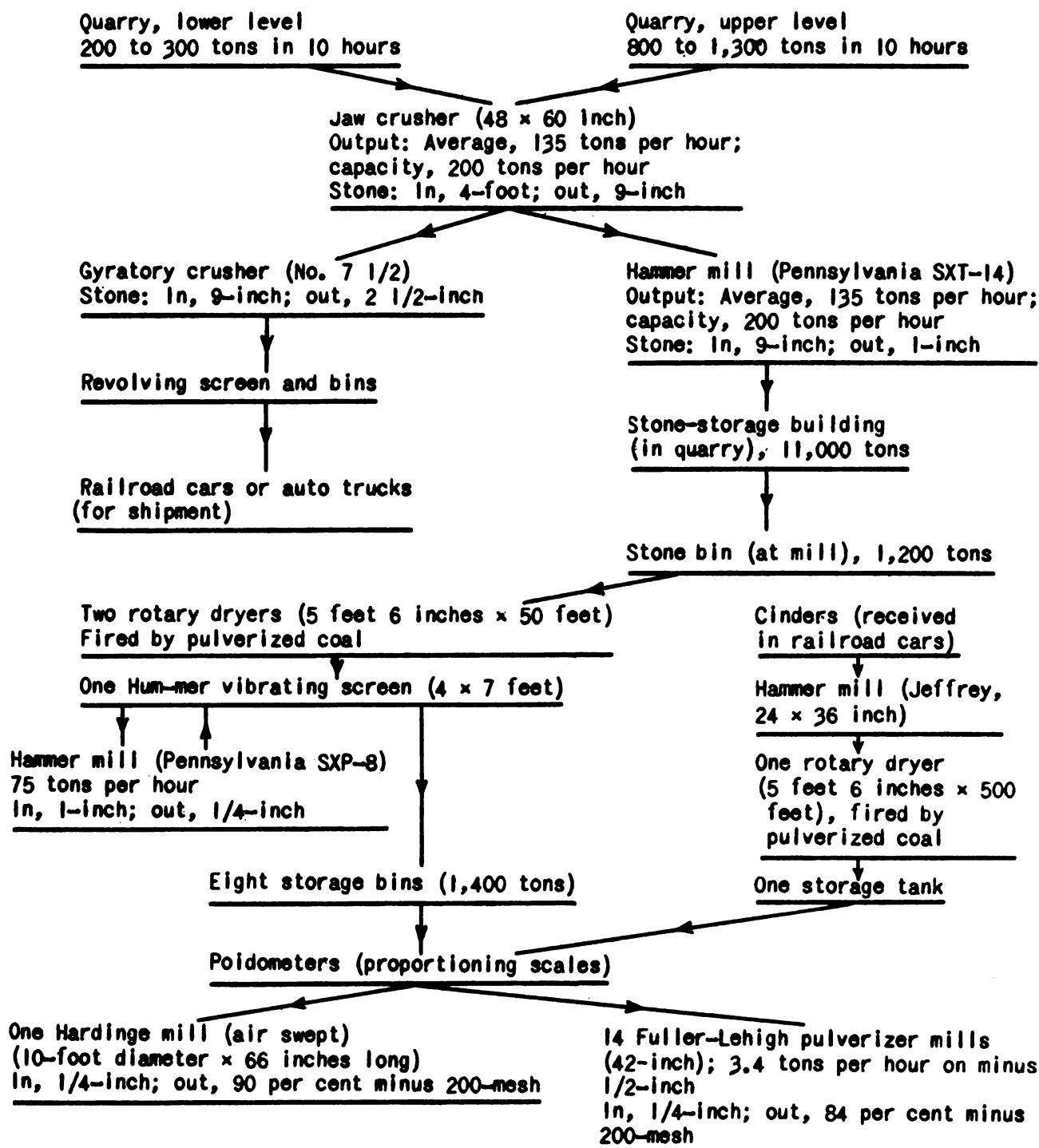


Figure 3.- Flow sheet showing machines, output, and material size